REMARKS

Upon entry of this amendment, claims 1-5, 7-13, 15, 16, 21 and 22 are all the claims pending in the application. Claims 6, 14 and 17-20 have been canceled by this amendment, and claims 21 and 22 have been added. No new matter has been added.

Applicants note that a number of editorial amendments have been made to the specification and abstract for grammatical and general readability purposes. Due to the number of changes made, a substitute specification and abstract are submitted herewith. No new matter has been added. Also enclosed is a marked-up copy of the original specification and abstract showing the changes incorporated into the substitute specification and abstract.

I.   Claim Objection

Claim 4 was objected to due to a minor informality. By this amendment, Applicants have replaced the term "sate" with --state--. Applicants thank the Examiner for pointing out this typographical error, and kindly request that the objection be withdrawn in view of the above-noted amendment.

II.   Claim Rejections under 35 U.S.C. § 112, second paragraph

Claims 1-7 and 17-20 were rejected under 35 U.S.C. § 112, second paragraph as allegedly being indefinite. In particular, the Examiner asserts that it is not clear that claims 2-7 and 17-20 further limit the apparatus of claim 1. In other words, the Examiner has taken the position that dependent claims 2-7 and 17-20 are improper dependent claims. Applicants respectfully disagree.

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In particular, Applicants point out to the Examiner that the MPEP explains that the "test as to whether a claim is a proper dependent claim is that it shall include every limitation of the claim from which it depends (35 U.S.C. 112, fourth paragraph) or in other words that it shall not conceivably be infringed by anything which would not also infringe the basic claim." See MPEP 608.01(n)(III).

As further explained in MPEP 608.01(n)(III), a "dependent claim does not lack compliance with 35 U.S.C. 112, fourth paragraph, simply because there is a question as to (1) the significance of the further limitation added by the dependent claim, or (2) whether the further limitation in fact changes the scope of the dependent claim from that of the claim from which it depends. The test for a proper dependent claim under the fourth paragraph of 35 U.S.C. 112 is whether the dependent claim includes every limitation of the claim from which it depends. The test is not one of whether the claims differ in scope" (emphasis added).

Furthermore, Applicants note that a patent applicant is free to recite features of an apparatus either structurally or functionally. As explained in MPEP 2173.05(g), "there is nothing inherently wrong with defining some part of an invention in functional terms" and as further set forth therein, a "functional limitation must be evaluated and considered, just like any other limitation of the claim, for what it fairly conveys to a person of ordinary skill in the pertinent art in the context in which it is used."

Based on the foregoing, Applicants respectfully submit that claims 2-7 and 17-20 are proper dependent claims, and therefore, kindly request that the Examiner reconsider and withdraw the above-noted rejection.

III. Claim Rejections under 35 U.S.C. § 102

Claims 1-20 were rejected under 35 U.S.C. § 102(b) as being anticipated by Birang et al. (U.S. 6,399,501).

Claim 1, as amended, recites the feature of a calculating unit for calculating a plurality of second characteristic values by obtaining average values of a predetermined number of the first characteristic values which are obtained from adjacent sampling points in one scan of the surface, wherein at least one of the first characteristic values is used redundantly in calculating one of the second characteristic values and another of the second characteristic values. Applicants respectfully submit that Birang does not disclose or suggest at least this feature of claim 1.

Regarding Birang, Applicants note that this reference discloses a CMP apparatus 20 that utilizes an optical monitoring system 40 for determining the amount of material that has been removed from the surface of a substrate (see col. 5, lines 12-15). In Birang, when performing the optical monitoring, a laser beam sweeps across the substrate, whereby the optical monitoring system 40 generates a series of intensity measurements I_1, I_2, I_3, ... I_N (see col. 5, lines 50-57).

As explained in Birang, for each sweep of the substrate, a value is extracted from the series of intensity measurements (see col. 5, lines 62-63). For example, the series of intensity measurements can be averaged to generate a mean intensity (I_{MEAN}), a minimum intensity (I_{MIN}) can be extracted, or a maximum intensity (I_{MAX}) can be extracted (see col. 5, line 64 – col. 6, line 1).

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Thus, in Birang, intensity measurements are calculated during each of a plurality of sweeps of the substrate, and for each of the sweeps, a value such as mean intensity (I_{MEAN}) or minimum intensity (I_{MIN}) can be determined.

As is clear from the description in Birang, however, while the intensity measurements for each sweep are analyzed when determining a value such as the mean intensity (I_{MEAN}) or minimum intensity (I_{MIN}), Applicants respectfully submit that Birang does not disclose or in any way suggest that average values of the intensity measurements are obtained from adjacent sampling points, nor does Birang in any way suggest that the intensity measurements can be used redundantly when calculating a value such as the mean intensity (I_{MEAN}) or minimum intensity (I_{MIN}).

In view of the foregoing, Applicants respectfully submit that Birang does not disclose, suggest or otherwise render obvious at least the above-noted feature of a calculating unit for calculating a plurality of second characteristic values by obtaining average values of a predetermined number of the first characteristic values which are obtained from adjacent sampling points in one scan of the surface, wherein at least one of the first characteristic values is used redundantly in calculating one of the second characteristic values and another of the second characteristic values, as recited in amended claim 1.

Accordingly, Applicants submit that claim 1 is patentable over the cited prior art, an indication of which is kindly requested. Claims 2-5, 7 and 8 depend from claim 1 and are therefore considered patentable at least by virtue of their dependency.

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Regarding claim 9, Applicants note that this claim recites the feature of calculating a plurality of second characteristic values by obtaining <u>average values</u> of a predetermined number of the first characteristic values which are obtained from <u>adjacent sampling points</u> in one scan of the surface, wherein at least one of the first characteristic values is <u>used redundantly</u> in calculating one of the second characteristic values and another of the second characteristic values.

For at least similar reasons as discussed above with respect to claim 1, Applicants respectfully submit that Birang does not disclose, suggest or otherwise render obvious at least the above-noted feature recited in claim 9. Accordingly, Applicants submit that claim 9 is patentable over Birang, an indication of which is kindly requested. Claims 10-13, 15 and 16 depend from claim 9 and are therefore considered patentable at least by virtue of their dependency.

IV. New Claims

Claims 21 and 22 have been added as new claims. Claim 21 depends from claim 1, and claim 22 depends from claim 9. Accordingly, Applicants submit that claims 21 and 22 are patentable at least by virtue of their dependency.

IV. Conclusion

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited.

If any points remain in issue which the Examiner feels may best be resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

Respectfully submitted,

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DESCRIPTION

POLISHED STATE MONITORING APPARATUS AND

POLISHING APPARATUS USING THE SAME

5

FIELD OF THE INVENTION

The present invention relates to a polished state monitoring apparatus for measuring a characteristic value of a surface to be polished of an object to be polished

10   such as a semiconductor wafer and deciding a timing of the end point of polish polishing, as well as a polishing apparatus having the polishing state monitoring apparatus.

BACKGROUND OF THE INVENTION

Chemical mechanical polishing (CMP) is already known

15   which removes irregularity irregularities from a surface of a semiconductor wafer to flatten the surface. In the case of chemical mechanical polishing, it is necessary to complete the polish polishing when a film to be polished such as an interlayer insulating film becomes a desired

20   thickness. Moreover, it may be requested to complete polish polishing when a film to be polished is removed and a base stopper film or barrier film appears like the case of STI (shallow trench isolation) or copper wiring film. As a means for satisfying these requests, a polished state

25   monitoring apparatus is known which detects an end point of chemical mechanical polishing by irradiating a semiconductor wafer by a light-projecting device and detecting a change in reflectivity of a surface to be

polished in accordance with the intensity of the light reflected from the wafer in order to prevent excessive or insufficient ~~polish~~ polishing.

To detect an end point of chemical mechanical ~~polish~~
5   polishing, a change in intensity of the light of a single-color light source, such as a semiconductor laser or a light emitting diode (LED), reflected from the polished surface or an optical characteristic such as spectral reflectance of white light reflected from the same may be
10 used. Further, a polished state monitoring apparatus is known which calculates a thickness of a film on a wafer by using the intensity of the light reflected from a semiconductor wafer.

Some of conventional polished state monitoring
15 apparatuses monitor a polished state of a semiconductor wafer, for example, measure a characteristic value such as a thickness by scanning a surface of a semiconductor wafer once every turn of a turntable on which a polishing material is set and sampling at a plurality of points every
20 scan period so as to obtain a characteristic value at each sampling point (region). Specifically, a value obtained by A/D-converting the intensity of the light reflected from the surface of a semiconductor wafer at each sampling point is successively plotted as a characteristic value (Refer to
25 Japanese Laid-open No. 2001-284300). In this case, if a light source is continuously lighted while irradiation light scans the surface of a wafer, the reflection intensity represents a region having a certain length along

a scan line. This is also referred to as a sampling point hereafter. In Fig. 1(a), a solid line shows a scan trajectory of irradiation light on a semiconductor wafer and a circle shows a sampling point.

5   In this case, the scan trajectory on the semiconductor wafer differs every scan because the rotational speed of a turntable on which a polishing material is set is normally different from that of a top ring to which the wafer is attached. For example, as shown

10 in Fig. 1(b), the first, second and third scans performed three consecutive times are performed along different trajectories. Points 1-1, ..., 1-17, 2-1, ..., 2-17, and 3-1, ..., 3-17 are sampling points when performing the sampling 17 times on each scan trajectory.

15   In many cases, as is well known, a profile of a surface to be polished becomes a shape roughly axis-symmetric to the rotational center of a semiconductor wafer. In monitoring the surface to be polished, if all characteristic values obtained through a plurality of times

20 of scans are mechanically arranged as shown in Fig. 8, a polished state of the surface to be polished at each scan is monitored. However, it is difficult to grasp a polished state at a specific position of a surface to be polished (e.g. wafer center) because characteristic values are

25 changed in each scan operation due to an effect by the above profile. Moreover, there is a problem that the progress of polish polishing cannot be easily confirmed from a characteristic value because of a difference of a

wiring pattern at each sampling point, a difference of a
slurry state at each sampling, and the influence of
electrical noise or the like.

DISCLOSURE SUMMARY OF THE INVENTION

5 Problems to Be Solved by the Invention

The present invention has been proposed to solve the
problems of the above prior art and the object of the
present invention is to provide a polished state monitoring
apparatus capable of easily confirming the progress of

10 polish polishing of an object to be polished and easily
detecting an end point of the polish polishing, and a
polishing apparatus having the polished state monitoring
apparatus.

Means for Solving the Problem

15 To achieve the above object, the invention of claim 1
in a first aspect provides a polished state monitoring
apparatus for obtaining a characteristic value indicating
the state of a surface to be polished of an object at each
sampling point every predetermined interval while scanning

20 the surface, and monitoring the progress of the polish
polishing of the surface by performing the scan a plurality
of times, said the apparatus comprising:

a light emitting unit capable of emitting light for
irradiating the surface to be polished; and

25 a computing unit for controlling a sampling timing of
the characteristic value and receiving light reflected from
the surface to generate the characteristic value,

the computing unit being operable to monitor a time

dependent variation of the generated characteristic value obtained from the sampling point at the same sampling timing every scan.

The invention of ~~claim 2~~ a second aspect is characterized in that the computing unit detects an end point of the ~~polish~~ polishing in accordance with the characteristic value obtained from pre-selected at least one sampling point of the same sampling timing.

The invention of ~~claim 3~~ a third aspect is characterized in that the pre-selected at least one sampling point of the same sampling timing is a sampling point substantially corresponding to the center of the surface.

The invention of ~~claim 4~~ a fourth aspect is characterized in that the computing unit selects a plurality of different sampling points at the same sampling timings, monitors each time dependent variation, and detects the end point of the ~~polish~~ polishing.

The invention of ~~claim 5~~ a fifth aspect is characterized in that the ~~polish~~ polishing is stopped when a specified number of sampling points among a plurality of different sampling points of the same sampling timings reaches the end point of the ~~polish~~ polishing.

The invention of ~~claim 6~~ a sixth aspect is characterized in that the computing unit outputs an average value of the characteristic values from a predetermined number of sampling points including one sampling point during the same scan and monitors a time dependent

variation of the average value.

The invention of ~~claim 7~~ a seventh aspect is characterized in that the computing unit outputs an average value of the characteristic values from a predetermined number of sampling points including one sampling point during the same sampling timing of each of the scans and monitors a time dependent variation of the average value.

The invention of ~~claim 8~~ an eighth aspect is characterized by a polishing apparatus including a polished state monitoring apparatus ~~as claimed~~ in any one of ~~claims 1 to 7~~ the first to seventh aspects.

The invention of ~~claim 9~~ a ninth aspect provides a polished state monitoring method for obtaining a characteristic value indicating the state of a surface to be polished of an object at each sampling point every predetermined interval while scanning the surface and monitoring the progress of the ~~polish~~ polishing of the surface, the method comprising the steps of:

performing the scan a plurality of times; and

monitoring a time dependent variation of the characteristic value obtained from the sampling point at the same sampling timing during each scan.

The invention of ~~claim 10~~ a tenth aspect is characterized by selecting at least one sampling point of the same sampling timing of each scan and detecting the end point of the ~~polish~~ polishing.

The invention of ~~claim 11~~ an eleventh aspect is characterized in that the at least one sampling point of

the same sampling timing is a sampling point substantially corresponding to the center of the surface.

The invention of ~~claim 12~~ a twelfth aspect is characterized by selecting a plurality of different sampling points at the same sampling timings and monitoring each time dependent variation to detect the end point of the ~~polish~~ polishing.

The invention of ~~claim 13~~ a thirteenth aspect is characterized by stopping the ~~polish~~ polishing when a specified number of sampling points among the different sampling points of the same sampling timings reach the end point of the ~~polish~~ polishing.

The invention of ~~claim 14~~ a fourteenth aspect is characterized by outputting an average value of the characteristic values from a predetermined number of sampling points including one sampling point during the same scan and monitoring a time dependent variation of the average value.

The invention of ~~claim 15~~ a fifteenth aspect is characterized by outputting an average value of the characteristic values from a predetermined number of sampling points including one sampling point at the same sampling timing of each of the scans and monitoring a time dependent variation of the average value.

The invention of ~~claim 16~~ a sixteenth aspect provides a polishing method characterized by executing a polished state monitoring method ~~as claimed~~ in any one of ~~claims 9 to 15~~ the ninth to fifteenth aspects.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1(a) and Fig. 1(b) are diagrams showing trajectories along which a surface to be polished of a semiconductor wafer is scanned and sampling points.

5   Fig. 2 is a diagram schematically showing the structure of a polishing apparatus having a polished state monitoring apparatus according to the present invention.

Fig. 3 is a diagram showing another optical measuring means of the polished state monitoring apparatus shown in

10   Fig. 2.

Fig. 4(a) is a diagram schematically showing a mutual positional relation between a turntable, a semiconductor wafer, a proximity sensor and a first window of the polishing apparatus in Fig. 2.

15   Fig. 4(b) is a diagram showing three scan trajectories and sampling points on the surface to be polished of a semiconductor wafer.

Fig. 5(a) is an explanatory diagram showing a method of indicating characteristic values obtained from sampling

20   points in accordance with the present invention.

Fig. 5(b) is a graph showing an example of a result of processing thickness values obtained from sampling points in accordance with the present invention.

Fig. 6(a) is a graph showing an example of a result

25   of averaging thickness values obtained from sampling points in accordance with the present invention.

Fig. 6(b) is a graph showing another example of a result of averaging thickness values in accordance with

another averaging technique of the present invention.

Fig. 7 is graph showing a result of performing an averaging operation in accordance with the present invention in comparison with cases in which such an averaging operation is not performed.

Fig. 8 is a graph in which characteristic values obtained during a plurality of scans are arranged in a time sequence.

~~BEST MODE FOR CARRYING OUT~~ DETAILED DESCRIPTION OF THE INVENTION

An embodiment of a polished state monitoring apparatus according to the present invention is described below in detail by referring to the accompanying drawings. In the drawings, the same or corresponding components are designated by the same symbols and any ~~double~~ duplicate description will be omitted hereafter.

Fig. 2 is an illustration schematically showing a whole structure of a polishing apparatus having a polished state monitoring apparatus according to the present invention. In Fig. 2, a polishing apparatus 1 has a polishing turntable 11 on one side of which a polishing cloth 10 is affixed, and a top ring 13 for holding a semiconductor wafer 12 to press it against a surface of the polishing cloth 10. The semiconductor wafer 12 is attracted and held by a lower surface of the top ring 13. A surface 14 of the polishing cloth 10 facing the semiconductor wafer 12 is a polishing surface contacting with the semiconductor wafer 12 with friction. In this

case, it is also possible to use an abrasive grain plate
obtained by solidifying fine abrasive grains such as CeO_2
with a binder such as a resin, instead of the polishing
cloth.

5   The center of the turntable 11 is supported by a
shaft 15 and a lower portion of the shaft 15 is connected
to a first driving motor (not shown). In this way, the
turntable 11 is rotated about the shaft 15 by the first
motor in the direction shown by an arrow X. A nozzle 16
10   for supplying a polishing solution onto the polishing cloth
10 is provided above the turntable 11.

       The top ring 13 is connected to a second driving
motor and an elevating cylinder (not shown) through a top
ring shaft 17 and can go up and down in the direction shown
15   by an arrow Y along the top ring shaft 17 and can rotate in
the direction shown by an arrow Z about the top ring shaft
17. In this way, the top ring 13 can press the
semiconductor wafer 12 held at a lower surface of the top
ring 13 toward the polishing cloth 10 at a desired pressure,
20   while rotating on its axis. In this case, the top ring 13
is supported so as not to move in the direction along the
surface of the semiconductor wafer 12.

       Therefore, the semiconductor wafer 12 is pressed
against the polishing cloth 10 on the turntable 11 and
25   polished while rotating together with rotation of the top
ring 13. At this time, the polishing solution is supplied
from the nozzle 16 onto the polishing cloth 10 and ~~polish~~
<u>polishing</u> is performed while the polishing solution exists

between the surface to be polished of the semiconductor
wafer 12 and the polishing cloth 10. In this case, pure
water can be used as the polishing solution if fixed
abrasive grains are used instead of the polishing cloth.

5   A polished state monitoring apparatus 18 for
optically measuring a characteristic value such as
thickness and color of an insulating film or metallic film
on the surface to be polished of the semiconductor wafer 12
so as to monitor the progress of the polish polishing is
10   provided at a proper place of the inside or lower surface
of the turntable 11. To realize the optical measurement, a
first window 19 is formed at a position of the polishing
cloth 10 facing the semiconductor wafer 12, and a second
window 20 is formed on the turntable 11 correspondingly to
15   the first window 19. Preferably these windows 19 and 20
are formed of a material having a high light transmittance
such as non-foamed polyurethane.

Another optical measurement means includes fluid-type
means having a fluid supply channel in the turntable 11.
20   As shown in Fig. 3, a fluid supply channel 30 and a fluid
discharge channel 31 are formed in the table instead of the
second window 20. A fluid such as pure water is injected
to the semiconductor wafer 12 and then discharged to the
outside through the fluid discharge channel 31. Two
25   optical fibers 32 and 33 are arranged in the fluid supply
channel 30, measurement light being projected to the
semiconductor wafer 12 through one of the optical fibers 32
and the light reflected from the semiconductor wafer 12

being received by the other of the optical fibers 33. The reflected light enables the progress of ~~polish~~ polishing to be monitored.

As shown in Fig. 2, a polished state monitoring apparatus 18 comprises a light emitting unit 21, a light receiving unit 22, a controller 23, a power supply 24, a cable 25 including a rotary connector, and a personal computer 26. The light emitting unit 21 emits light for irradiating the polished surface of the semiconductor wafer 12. The light receiving unit 22 receives light reflected from the polished surface irradiated with the light emitted from the light emitting unit 21, divides the reflected light into respective wavelength components and outputs electrical signals representative of intensities of light of the divided wavelength components. The controller 23 controls start and end timings of operation of the light emitting unit 21 and light receiving unit 22. The power supply 24 supplies power necessary for operations of the light emitting unit 21, light receiving unit 22 and controller 23. Preferably the light emitted from the light emitting unit 21 enters substantially vertically to the polished surface of the semiconductor wafer 12.

It is possible to use any unit as the light emitting unit 21 and light emitting means which emits light having a wavelength band including white light is preferable. The light emitting unit 21 can be a pulse turned-on type such as a xenon flash lamp or a continuously lighted type such as a tungsten halogen lamp.

An electrical signal outputted from the light receiving unit 22 is sent to the controller 23 and causes the controller 23 to generate spectrum data for the light reflected from the semiconductor wafer 12. The output of

5   the controller 23 is connected to the personal computer 26 through the cable (including a rotary connector) 25 passing through the turntable 11 and shaft 15. Thus, the spectrum data generated by the controller 23 is sent to the personal computer 26 through the cable (including the rotary

10   connector) 25.

Specifically, light emitted from the light emitting unit 21 is irradiated to and reflected from the surface to be polished of the semiconductor wafer 12, passes through the first window 19 and second window ~~22~~ 20, and is

15   received by the light receiving unit 22. The light receiving unit 22 divides the received light into a plurality of wavelength components, generates spectrum data which corresponds to each sampling point in accordance with an amount of light of each wavelength component, and sends

20   the data to the personal computer 26.

The personal computer 26 serving as a computing unit is programmed so as to compute various characteristic values including thickness and color of the surface to be polished of the semiconductor wafer 12 in accordance with

25   the spectrum data sent from the controller 23. The personal computer is further programmed to determine a point of time to stop the ~~polish~~ polishing or timings of changes in ~~polish~~ polishing conditions, such as rotational

speed of the turntable and the top ring, pressure to be
applied to a plurality of pressing regions formed on the
top ring, and the types of slurry (these are also included
in "polish end operation") in accordance with a time
5   dependent variation of calculated characteristic values.
Such a determination is sent from the personal computer 26
to a control unit (not shown) which controls the operation
of the polishing apparatus. The personal computer 26 can
also receive information on polishing conditions from the
10   control unit.

In addition, as shown in Fig. 2, in order to detect a
rotational position of the turntable 11, a proximity sensor
27 is provided at a proper position of a lower surface of
the outer periphery of the turntable 11. A dog 28 is
15   disposed at a position corresponding to the proximity
sensor 27. In this way, the proximity sensor 27 detects
the dog 28 every turn of the turntable 11 and sends an
output to the controller 23 every time the dog 28 is
detected, thereby enabling the controller 23 to detect a
20   rotational angle with respect to a reference position of
the turntable 11.

Fig. 4(a) is a top view schematically showing a
mutual positional relation among the turntable 11,
semiconductor wafer 12, first window 19, proximity sensor
25   27 and dog 28 at the time when the proximity sensor 27
comes to lie on the line that connects the center 40 of the
turntable 11 with the dog 28. The top ring 13 is
positioned so that the center 41 of the semiconductor wafer

12 exists on a circular trajectory 42 of the first window
19. Consequently, by rotating the turntable 11 and the top
ring 13 in the same direction, and by operating the light
emitting unit 21 at a predetermined interval during when

5 the first window 19 exists is under the semiconductor wafer
12 in the case of a pulse turned-on type light source so as
to sample the polished surface at a sampling timing of a
predetermined interval, it is possible to obtain the
reflectivity, thickness and color of the polished surface

10 at a plurality of sampling points S1, S2, ..., and Sm on
the trajectory 42. It is noted that a time period from a
time when the proximity sensor 27 detects the dog 28 up to
a time when the pulse-turned-on type light source starts
operation or when sampling of light reflected from the

15 polished surface is started can be adjusted to a
predetermined value in accordance with the rotational speed
of the turntable 11.

    When the turntable 11 is rotated at a speed of, for
example, 60 turns per minutes minute and the top ring 13 is

20 rotated at a speed of, for example, 70 turns per minutes
minute in the same direction, the trajectory for the first
window 19 to scan the surface to be polished of the
semiconductor wafer 12 is shifted in the same direction
every turn about the center 40 of the semiconductor wafer

25 12 due to the difference between the rotational speeds.
Such a shift appearing during three consecutive scans can
be illustrated as shown in Fig. 4(b). Assuming that the i-
th scan is called scan "i" and that the sampling point at

the k-th sampling timing in the scan "i" is designated as

"i-k", Fig. 4(b) shows the following:

(1) Characteristic values are obtained at m sampling points

1-1, 1-2, ..., 1-m along a scan trajectory T_1 in the first

5   scan;

(2) Characteristic values are obtained at m sampling points

2-1, 2-2, ..., 2-m along a scan trajectory T_2 in the second

scan; and

(3) Characteristic values are obtained at m sampling points

10   3-1, 3-2, ..., 3-m along a scan trajectory T_3 in the third

scan.

     Fig. 5(a) is an illustrative diagram showing the

progress of polish polishing, by interconnecting

characteristic values for the same sampling numbers, that

15   is, the same sampling timings by straight lines during the

first to third scans.

     In the polished state monitoring apparatus according

to the present invention, if the rotational center of the

top ring does not move, such a fact is used that the k-th

20   sampling point, that is, the sampling point at the k-th

sampling timing, is at almost the same distance from the

center 41 of the semiconductor wafer 12 regardless of the

number of times of scan. In other words, the inventors

have noted that it is possible to easily and accurately

25   confirm the progress of polish polishing by tracing

characteristic values obtained from a sampling point group

of the same number (for example, a group of the first

sampling points 1-1, 2-1, 3-1, ..., i-1, ...) in each scan.

This is because the profile of a surface after being
polished has an almost axis-symmetric shape, as is well
known in a chemical mechanical polishing apparatus.

In other words, classifying many sampling points in a
plurality of times of scans and referring to a group of
sampling points at the first sampling timing as a sampling
point group 1, a group of sampling points at the second
sampling timing as a sampling point group 2, ..., and a
group of sampling pints at the k-th sampling timing as a
sampling point group k, the polished state monitoring
method and apparatus according to the present invention are
operable to monitor the progress of polish polishing, by
arranging, in order of time, characteristic values obtained
from sampling points in the same sampling point group.

For example, assuming that a thickness is used as a
characteristic value, it is possible to obtain, as shown in
Fig. 5(b), a thickness curve A obtained from the sampling
point group 1, a thickness curve B obtained from the
sampling point group 3 and a thickness curve C obtained
from the sampling point group 8 in the first scan, second
scan, ..., and i-th scan. Assuming that one scan has
fifteen sampling points, the sampling point group 1 exists
in a region close to an end portion of the semiconductor
wafer 12 and the sampling point group 8 exists in a region
near the center of the semiconductor wafer 12.

In general, if the sampling points at the sampling
timing of the same number lie on different scan
trajectories, wiring patterns corresponding to those

sampling points differ, or time dependent variation of characteristic values fluctuate because of differences in step characteristics or uniformity across the surfaces. In many cases, as shown in Fig. 5(b), a fluctuation at an end

5 portion of the semiconductor wafer 12 is larger than that near the center thereof. In reality, for the purpose of detecting the end point of ~~polish~~ polishing by picking more stable characteristic values, it is preferable to be able to arbitrarily select sampling points thereby detecting the

10 end point from limited positions from which stable characteristic values can be obtained.

For example, the fluctuation of characteristic values is small in the region close to the center 41 of the semiconductor wafer 12 as is known from the solid line C in

15 Fig. 5(b) showing the thickness obtained from the sampling points in the sampling point group 8. Therefore, if attention is focused on such sampling points having a small fluctuation of characteristic values, it is possible to accurately detect the end point of polish with small

20 fluctuation.

Further, even if characteristic values are obtained from a plurality of sampling points during one scan, it is not always necessary to monitor the characteristic values from all the sampling points nor detect the end point by

25 using the characteristic values from all the sampling points. It is also possible to monitor the progress of ~~polish~~ polishing by selecting a desired number of sampling points out of the sampling points obtained during

one scan to plot the characteristic values from the sampling points at the same sampling timings as those of the selected sampling points.

If a specified number of characteristic values corresponding to the above selected sampling points are considered to have reached the end point, it is assumed that the semiconductor wafer 12 has reached the end point of ~~polish~~ polishing. For example, if it is assumed that the specified number of characteristic values is one, the ~~polish~~ polishing can be stopped at the sampling point at which the ~~polish~~ polishing has been done the fastest among the sampling points of the selected sampling point groups. This makes it possible to end a polishing operation earlier. Further, by adopting the same specified number as the number of selected sampling points, the ~~polish~~ polishing can be ended by focusing attention on the sampling point at which the ~~polish~~ polishing is done the slowest among the selected sampling points. In this way, it is possible to properly adjust the timing to end the ~~polish~~ polishing by monitoring, in parallel, changes in characteristic values obtained at sampling points at different sampling timings.

In actuality, in order to easily grasp the progress of ~~polish~~ polishing, it is preferable to use a graph having small noises or small local fluctuations. It is necessary to detect a characteristic point (such as threshold, maximum value or minimum value) with respect to a time dependent variation of characteristic value slightly before

a target point of time in order to detect the end point of
the ~~polish~~ polishing. Also for this reason, it is
preferable to remove and smooth noises or local
fluctuations from a graph of a time dependent variation of

5   characteristic value. One technique therefor is to
generate average values of characteristic values obtained
from a plurality of sampling points in one scan, each
average value being an average of a characteristic value
and a predetermined number of previous characteristic

10 values and a predetermined number of subsequent
characteristic values. Those average values are used as
second characteristic values to monitor the progress
of ~~polish~~ polishing. In other words, ~~focussing~~ focusing
attention on each sampling point, it is permitted that each

15 sampling point is used redundantly in order to calculate
average values of characteristic values for that sampling
point and also for other sampling points.

  For example, assuming that m = 11 in Fig. 4(b) and
that characteristic values obtained from the sampling

20 points 1-1, 1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 1-8, 1-9, 1-10,
and 1-11 in the first scan are designated as a11, a12, a13,
a14, a15, a16, a17, a18, a19, a110 and a111, the second
characteristic values A11, A12, A13, A14, A15, A16, A17,
A18, A19, A110 and A111 can be calculated in the following:

25   A11 = a11
  A12 = (a11 + a12 + a13)/3
  A13 = (a12 + a13 + a14)/3
  A14 = (a13 + a14 + a15)/3

$$A15 = (a14 + a15 + a16)/3$$

$$A16 = (a15 + a16 + a17)/3$$

$$A17 = (a16 + a17 + a18)/3$$

$$A18 = (a17 + a18 + a19)/3$$

5 $$A19 = (a18 + a19 + a110)/3$$

$$A110 = (a19 + a110 + a111)/3$$

$$A111 = a111.$$

It is noted that the above shows simple arithmetic averages without weight, but an averaging technique is not

10 limited to the above. For example, the averaging technique can be a harmonic average, a geometrical average or a midpoint value. In a similar manner, in other scans, an averaging operation is performed by permitting a redundant use of characteristic values obtained from individual

15 sampling points and the second characteristic values A21 - A211, A31 - A311, ..., Ai1 - Ai11, ... can be calculated. Then, the second characteristic values having the same number which appears following the number indicating the times of scan (for example, 1 next to A in the case of A12)

20 are called as "the second characteristic values having the same number" and plotted. Specifically, groups of the second characteristic values having the same numbers, that is, a characteristic value group 1 comprised of A11, A21, ..., Ai1, ..., a characteristic value group 2

25 comprised of A12, A22, ..., Ai2, ..., and a characteristic value group 3 comprised of A23, ..., Ai3, ... are made up and the second characteristic values belonging to a characteristic value group are plotted for respective

characteristic value groups, thereby obtaining curves
corresponding to Figs. 5(a) and 5(b).

In this case, it is possible that the second
characteristic values are average values of characteristic
5   values obtained from any number of adjacent sampling points.
It is also possible that the characteristic values from the
vicinity of the center 31 of the semiconductor wafer 12 are
not averaged. In the above example, it is possible that
A15 = a15, A16 = a16 and A17 = a17. As will be understood
10   from the above, because average values of characteristic
values are obtained from one sampling point and previous
and subsequent sampling points, an averaging operation can
be performed even if there are a small number of sampling
points, thereby bringing about such an advantage that a
15   profile of a surface to be polished can be easily grasped.

Fig. 6(a) shows a result of operation where the
second characteristic values are obtained by performing the
above averaging operation for every scan, as described
above, and the second characteristic values having the same
20   number are plotted. The solid line is obtained by plotting
the second characteristic values belonging to the
characteristic value group 8 in the above example and the
dotted line is obtained by plotting the second
characteristic values belonging to the characteristic value
25   group 3 in the above example. Such an above averaging
technique as described above is called as "space average".

Fig. 6(b) shows a graph D of characteristic values
obtained without the above averaging operation and a graph

E obtained by applying another averaging technique to the characteristic values. The graph D is obtained by plotting the characteristic values obtained from the sampling point 8 near the center of a semiconductor wafer and the graph E

5   is time-averaged values of the sampling point 8. In this example, five points are averaged and a characteristic value $B_{i,k}$ for the sampling point k of the i-th scan is expressed as

$$B_{i,k} = (a_{i-4,k} + a_{i-3,k} + a_{i-2,k} + a_{i-1,k} + a_{i,k})/5.$$

10   This is called ~~as~~ "time average".

Comparing the graphs in Fig. 5(b) with the graphs in Fig. 6(a), it is understood that noises or local fluctuations can be ~~reduces~~ <u>reduced</u> by performing such an averaging technique as described above to obtain the second

15   characteristic values and by monitoring the second characteristic values of the same number. Further, as shown in Fig. 6(b), the same advantage can be obtained through time averaging though a phase delay δ is involved. It is possible to execute either the space averaging or the

20   time averaging, and further time averaging can be applied to the second characteristic values generated by the space averaging.

Fig. 7 shows a profile of a semiconductor wafer having swells (irregularities) on its surface to be

25   polished and is used to explain advantages of the space averaging. When measuring a thickness value at fifteen sampling points during one scan, raw data shown by the broken line L has been obtained. Then, average values of

the thickness values from five adjacent sampling points are calculated in accordance with the polished state monitoring method according to the present invention, permitting redundant use of the thickness values, the solid line N has been obtained. It is noted that the averaging is not performed at end portions of the surface to be polished, and that an average value of the thickness values is obtained from three sampling points located one point inside of the end. In contrast, dividing fifteen sampling points into three regions each having five sampling points without overlap and obtaining respective average values, the dotted line M has been obtained.

As understood from Fig. 7, a polished state monitoring apparatus according to the present invention can be used to grasp a profile of the whole polished surface of a semiconductor wafer after smoothing local irregularities of the surface of the semiconductor wafer. As a result, in this example, it is possible to detect an end point of the ~~polish~~ polishing by ~~focussing~~ focusing attention on portions near the center of the polished surface where the ~~polish~~ polishing is done relatively fast and portions outside of the central portions where the ~~polish~~ polishing is done slowly. It is noted that the number of sampling points required for the averaging operation is preferably determined every sampling point by considering the number of sampling points existing during one scan and a degree of fluctuation of the characteristic values.

Some embodiments of a polished state monitoring

apparatus according to the present invention have been described heretofore. However, the present invention should not be limited to these embodiments. For example, scan trajectories ~~has~~ have been described to be lines

5 passing through the center of a surface to be polished, as shown in Fig. 3(b). However, if the position of the top ring is fixed, the scan trajectory may pass through a point other than the center of the surface to be polished. This is because, if the top ring is fixed, sampling points of

10 the same number are arranged at substantially the same distance from the center of the surface to be polished.

INDUSTRIAL APPLICABILITY

As understood from the above described, the present invention has such advantages as follows:

15 (1) Because a time dependent variation of characteristic values obtained from sampling points of the same number are used, it is possible to easily grasp the progress of ~~polish~~ polishing of an object to be polished;

(2) Because a characteristic value obtained from a

20 sampling point may be actually temporally fluctuated finely depending on the state of the polished surface of an object, it becomes easy to detect the timing of an end point of ~~polish~~ polishing by selecting specific sampling points from which stable characteristic values are obtained;

25 (3) Focusing attention on central sampling points of all the sampling points during one scan and monitoring the progress of ~~polish~~ polishing near the center of an object to be polished, it is possible to detect an end point of

~~polish~~ polishing accurately with a small fluctuation;

(4) Focusing attention on a desired number of sampling points and monitoring the progress of ~~polish~~ polishing, it is possible to simultaneously monitor a

5 portion at which ~~polish~~ polishing is done fast and portions at which ~~polish~~ polishing is done slowly, thereby adjusting a timing of detecting an end point of the ~~polish~~ polishing;

(5) Averaging characteristic values obtained from one sampling point in each scan in such a manner that the

10 characteristic values are used redundantly to calculate the second characteristic values, local fluctuations present on a surface to be polished are smoothed and a profile of the surface to be polished can easily be grasped. Because redundant use is allowed, the present invention is

15 particularly effective when the number of sampling points during one scan is small; and

(6) Because a polished state monitoring apparatus is provided which enables the progress of ~~polish~~ polishing to be easily grasped, it is possible to accurately detect an

20 end of ~~polish~~ polishing of an object to be polished such as a semiconductor wafer.

ABSTRACT

A polished state monitoring apparatus capable of
easily grasping the progress of ~~polish~~ polishing is
5   provided. The polished state monitoring apparatus monitors
the progress of ~~polish~~ polishing of a surface to be
polished by obtaining a characteristic value indicating a
state of the polished surface of an object ~~12~~ at each
sampling point every predetermined interval while scanning
10   the surface. The apparatus ~~comprises~~ includes light
emitting means ~~21~~ capable of emitting light for irradiating
the surface and computing units ~~26~~ for receiving light
reflected from the surface to generate a characteristic
value. Then, the apparatus fetches the characteristic
15   values obtained from the sampling points at the same
sampling timing during each scan and outputs the
characteristic values. This enables the progress of
the ~~polish~~ polishing to be monitored in accordance with the
distance from the center of the surface.

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